SOLUTIONS FOR DYNAMIC MECHANICAL ANALYSIS (DMA)

STEP LAB

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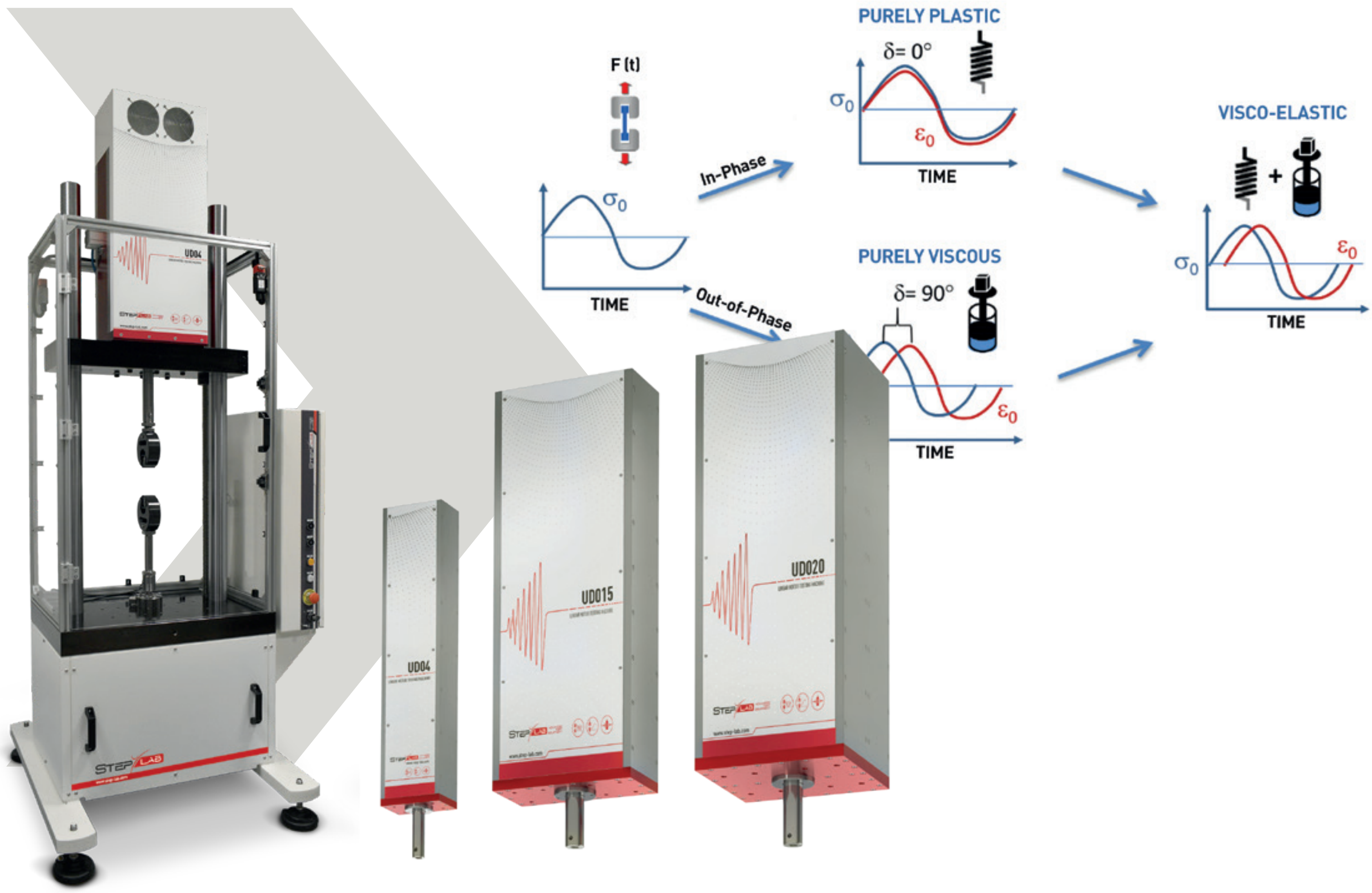
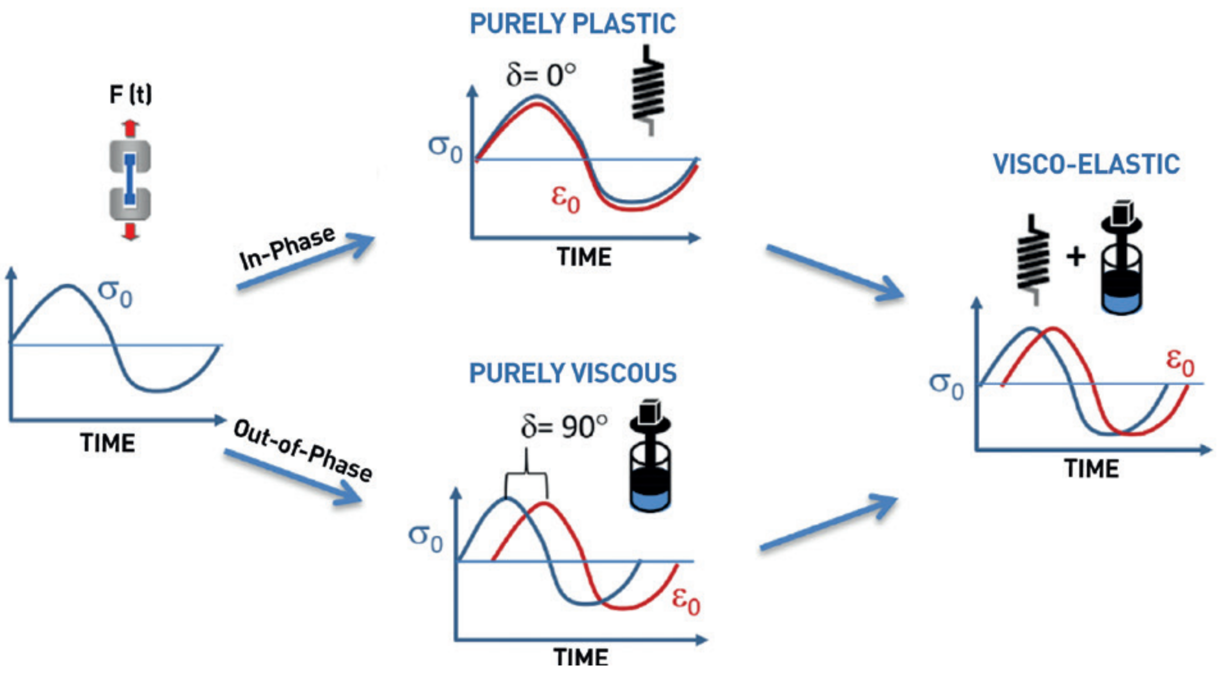


Description

The full electric electrodynamic machines produced by STEP Lab cover a wide range of applications, from static to high dynamic test types. The excellent performances of the linear brushless motors which power these machines allow to satisfy the highest performances required to determine the mechanical dynamic characteristics of viscoelastic materials, such as plastics and rubbers.

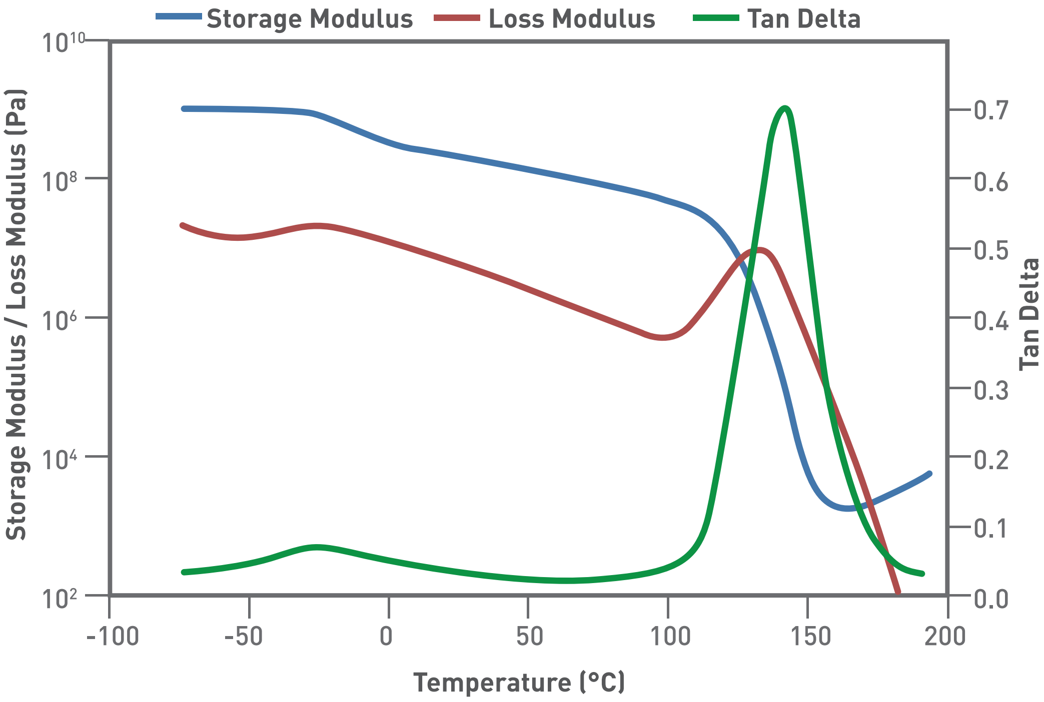
The Dynamic Mechanical Analysis (DMA) is entirely managed by the software Test Center and its complete set of modules for accurately set-up the test, supervisor the execution, analyze and process the generated data, ending up with an automatic report generation with a full customizable report layout.

DYNAMIC MECHANICAL ANALYSIS (DMA) OVERVIEW



Dynamic Mechanical Analysis (DMA) is a technique that is widely used to characterize a material's properties as a function of temperature, time, frequency, stress, atmosphere or a combination of these parameters.
Applying a small deformation to a sample in a cyclic manner it is possible to study the materials response to stress, temperature, frequency and other values. The sample can be subjected by a controlled stress or a controlled strain. In DMA the viscoelastic property of the material is studied applying a sinusoidal force (stress σ) and measuring the resulting displacement (strain ε). For a perfectly elastic solid, the resulting strain and the stress will be perfectly in phase. For a purely viscous fluid, there will be a 90 degree phase lag of strain with respect to stress. Viscoelastic polymers have the characteristics in between where some phase lag will occur during DMA tests.
The fundamental parameters and relations of the DMA analysis are:

→ Stress	$\sigma = \sigma 0 \sin (t\,\omega + \delta)$
→ Strain	$\varepsilon = \varepsilon 0 \sin (t\,\omega)$
→ ω:	frequency of strain oscillation
→ t:	time
→ δ:	phase lag between stress and strain waves
→ δ = 0	for purely elastic materials
→ δ = 90	for purely viscous materials
→ 0° < δ < 90°	for polymers
→ Storage modulus	$E' = \frac{\sigma 0}{\varepsilon 0} \cos \delta$. This parameter measures the stored energy, representing the elastic
→ Loss modulus	$E'' = \frac{\sigma 0}{\varepsilon 0} \sin \delta$. This parameter measures the energy dissipated as heat, representing →
Phase angle	$\delta = \arctan \frac{E''}{E'}$. This parameter provides information about the interaction of the elastic and viscous parts of the material.



Visco-elastic properties as a function of temperature

STEP LAB SOLUTIONS FOR DMA

UD04: example of machine for DMA tests type

The full STEP Lab's experience in dynamic and high dynamic test types has allowed to realize machines with excellent performances in order to satisfy the high demand requirements need to obtain good results from the DMA analysis.

Typical challenges of the DMA tests are:

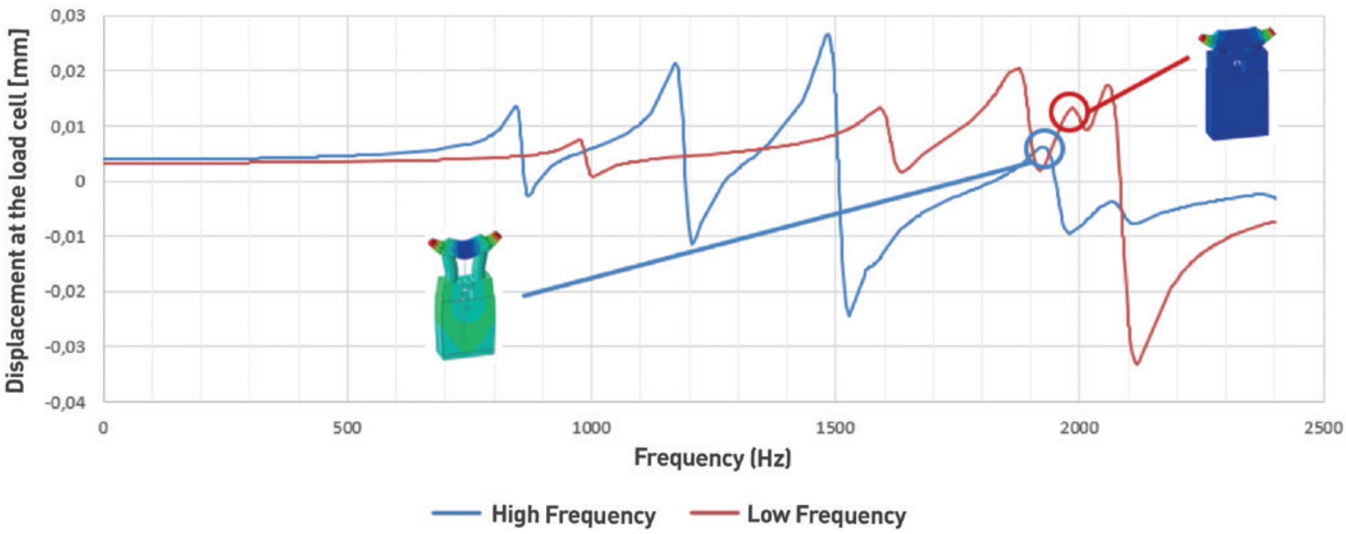
- The difficulty to measure motion and force accurately at high frequencies.
- The ability to accurately measure the phase lag between the applied displacement and resulting force.
- Sweeps of excitation frequency, stress, strain, and temperature.
- Guaranteeing the right PID tuning and control stability and accuracy even although the specimen behavior could sometimes change of orders of magnitude during the test
- Combining and synchronizing mechanical and temperature excitations to specimens.
- Ensuring the specimen temperature is even.

Machine characteristics

As highlighted, there are many aspects of the test system that can influence testing accuracy.

STEP Lab full electric machines ensure very stiff response to prevent unwanted resonances which could impact the data accuracy. This goal is achieved by:

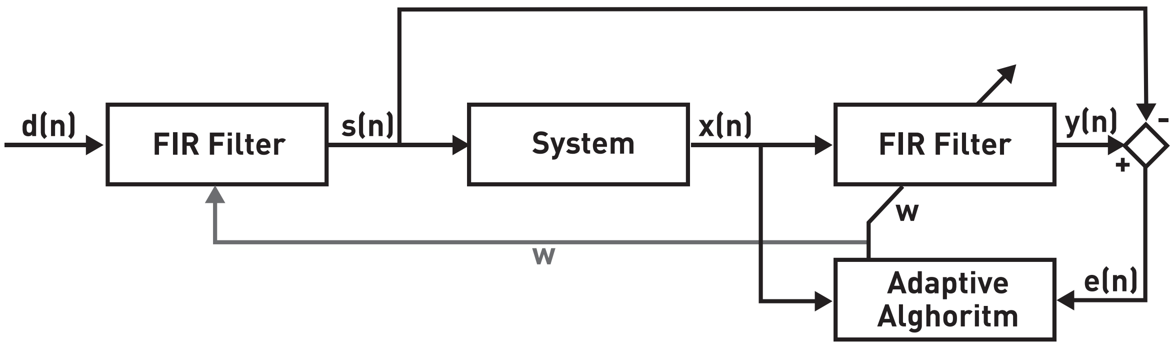
- robust frame with an optimized stiffness/weight ratio thanks to intensive FEM analysis, both static and dynamic to shift the natural resonant frequency to the highest values.
- direct motion application by linear motor without the need of mechanic transmissions.



Example of a machine frequency response analyzed by means of FEM tools

STEP Lab has developed a robust control system (TEST Controller), which is be able to accurately measure forces and displacements and can accomplish an optimal control of the test thanks to proprietary algorithms:

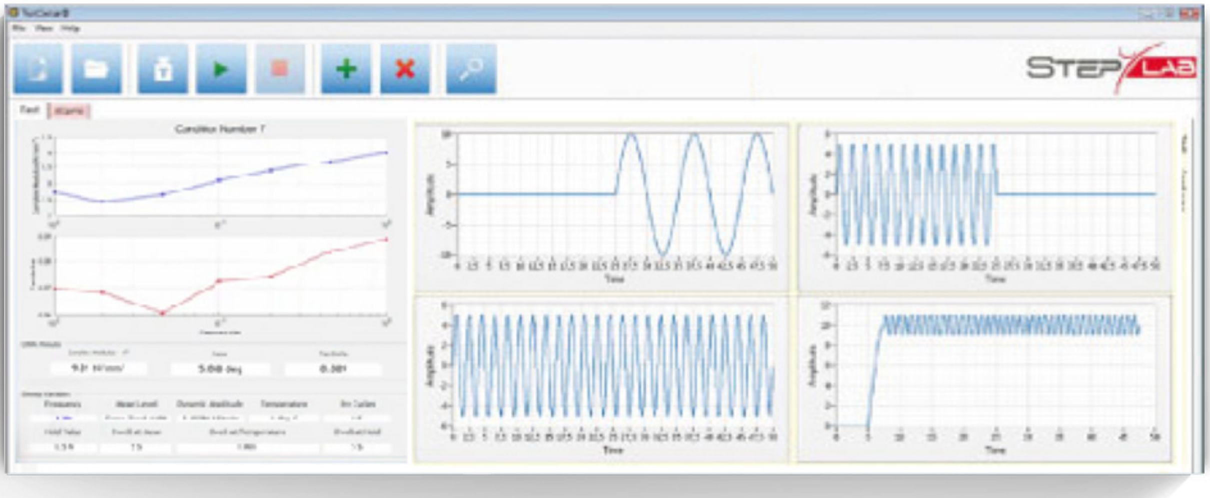
- Forces are evaluated by load cells with optionally acceleration compensation techniques
- Load cells are read by the controller with a high speed, 24 bit ADC converters
- Displacements are measured by means of optical linear encoders with very high resolutions (up to 0,05 μm) or by means of top performance LVDT sensors
- PID parameters are changed automatically during the test execution in order to adapts to the actual response of the specimen.
- Machine Learning and Adaptive Inverse Control are optional toolbox available.



The Adaptive Inverse Control algorithm used by the Test Controller to optimize the machine control

STEP Lab has developed a powerful software (TEST Center), which is a complete software solution to manage the entire range of machines produced:

- Static and Dynamic test management by the same application.
- Mono and multi axis machines can be managed.
- Simultaneous management and synchronization of different sub-systems like axes, climatic chamber, automatic grips, etc.



The Test Center main interface during a DMA test execution

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